The crystals are harvested during a three-month period each fall on a five day per week around-the-clock schedule. A special mechanized skimmer deposits the crystals into a conveyor system which loads special salt trains operating on movable tracks. The salt is transported by the train to the processing plant where it is washed and refined as required for marketing purposes.

Bittern Production

The concentration process takes place through a series of nine systems of ponds. In the first six systems of ponds, evaporation takes place during the scheduled evaporating season from April through October of each year. Brine is progressively drained or pumped from one pond system to the next as evaporation in the next pond requires replacement. By the time the brine reaches the sixth pond system, its specific gravity has reached 1.099 (12.9° Bé) and its volume has been reduced to about one-half of that taken from the Bay. By this stage, the suspended matter has settled, the carbonates have precipitated and the precipitation of gypsum begins.

Between pond systems seven through nine, the evaporation process continues until the brine is fully saturated with salt, roughly at 25.6° Bé. However, the evaporation process continues until the specific gravity reaches 26.0° Bé by which time the brine has reached the ninth or so-called pickle pond.

The brine has then been reduced in volume to about 10 percent of the volume of bay water first taken in, and most of the gypsum has precipitated.

From the pickle pond, the brine is transferred to the crystallizing ponds where the sodium chloride crystallizes. Pickle enters at approximately 25.6° Bé and bittern is withdrawn at 29° Bé. The bittern is transferred to bittern ponds where continued evaporation raises the specific gravity to between 30° and 32° Bé, depending on the storage time. Depending upon the length of time in storage, the bittern reaches a maximum specific gravity of about 36° Bé, beyond which no evaporation takes place.

For every million tons of salt produced, 38.3 million tons of bay water are required, illustrating the tremendous volumes of bay water and brine that must be transported during the concentrating and evaporation process. One million tons of bittern are produced for each million tons of salt produced, also illustrating the magnitude of the bittern disposal problem.

Based on present production levels, slightly more than a million tons of bittern are produced at the three south Bay plants as shown in Table 1.

TABLE 1

CURRENT BITTERN PRODUCTION
FROM SOUTH BAY PLANTS

Plant	Thousands of tons/year
Newark	540
Baumberg	180
Redwood City	300
Total	1,020

II. LAWS AND REGULATIONS GOVERNING THE DISCHARGE OF BITTERN TO SAN FRANCISCO BAY

Several Federal and State laws and regulations have a bearing on the discharge of industrial wastes to San Francisco Bay. On the Federal level, the Environmental Protection Agency and the Corps of Engineers administer programs having application to the proposed discharge. On the State level, the State Water Resources Control Board, the California Regional Water Quality Control Board and the California Department of Fish and Game have specific responsibilities and interests concerning such discharges.

Corps of Engineers

By virtue of the Rivers and Harbors Act of 1899, the Corps of Engineers exercises jurisdiction over the navigable waters of the United States, including San Francisco Bay, with respect to both the construction and maintenance of structures, and also with respect to the discharge of industrial wastes therein. New regulations governing the issuance of permits under the 1899 Act became effective on April 4, 1971.

The regulations cite several Federal laws which will be considered in the administration of the Act, and which will govern the issuance of permits thereunder. Those Acts affecting the marine environment that are specifically mentioned in the regulations include the Federal Water Pollution

Control Act, the Water Quality Improvement Act of 1970, the National Environmental Policy Act of 1969, the Fish and Wildlife Act of 1956, the Migratory Marine Game Fish Act and the Fish and Wildlife Coordination Act. The regulations specifically require that the discharge of industrial wastes into navigable water shall be in accordance with a permit issued under the Act.

In arriving at a decision whether or not to issue a permit, the Corps of Engineers is required under the regulations to confer with officials at the state, interstate, and federal levels having responsibility for water quality improvement. In this regard, the views of the State Water Resources Control Board and the Regional Water Quality Control Board are solicited. The Environmental Protection Agency (EPA) is specifically required to advise the Corps of Engineers of the following:

(1) The meaning and content of applicable water quality standards.

(2) The application of water quality standards to the proposed discharge or deposit, including the likely impact of the proposed discharge or deposit.

(3) The permit conditions required to comply with applicable water quality standards.

(4) The permit conditions required to carry out the purposes of the Federal Water Pollution Control Act where water quality standards are not applicable in whole or in part.

(5) The protection afforded fish and wildlife resources by water quality standards, if any.

(6) The interstate water quality effect of the proposed discharge or deposit.

(7) The recommended duration of the permit.

The regulations require that the EPA provide the Corps of Engineers with a specific recommendation as to whether or not the requested permit should be issued. They also provide a means for resolving any differences of views that may arise between the Corps and the EPA, but grant to the EPA final authority on issues regulated by the Federal Water Pollution Control Act.

Under provisions of the National Environmental Policy Act of 1969, the Corps of Engineers is required to issue an environmental impact report on a proposed waste discharge which would be regulated by any permit it may issue under the Act. Chapter VI of this report contains a discussion of the items required to be included in the impact report for the proposed waste discharge.

Environmental Protection Agency

While the EPA has no permit-issuing authority at present with respect to the proposed discharge of bittern, the agency does have substantial authority over states in the setting of water quality standards. It has also been shown that the EPA has significant authority with respect to the Federal laws regulating the discharge of industrial wastes through outfall facilities in navigable waters.

The EPA directly administers several laws and regulations affecting the preservation of the quality of interstate waters. These include the Federal Water Pollution Control Act (FWPC Act). Companion laws administered by the EPA, in addition to those previously mentioned in current regulations under the 1899 Act, include the Water Quality Act of 1965 and the Clean Water Restoration Act of 1966.

Sections 1 and 10 of the FWPC Act declare that it is the policy of the Congress to recognize and preserve the primary responsibilities and rights of the States in preventing and controlling water pollution, and the State and interstate action to abate the pollution of navigable waters shall be encouraged. A procedure for the establishment of water quality standards applicable to interstate waters is specifically set forth in Section 10 of the Act.

With the foregoing encouragement, and following extensive hearings before the Regional Water Quality Control Board and the State Water Quality Control Board, the State Board adopted a water quality control policy for San Francisco Bay in 1967, entitled "Water Quality Control Policy for Tidal Waters Inland From the Golden Gate Within the San Francisco Bay Region." This policy was determined to meet the criteria established in the FWPC Act and was subsequently adopted as Federal water quality standards in the Code of Federal Regulations. A copy of the water quality objectives taken from the 1967 policy is set forth in Appendix C.

State Water Resources Control Board

The California Legislature substantially increased the scope of regulatory powers and functions of the State Water Resources Control Board (State Board) and its Regional Water Quality Control Boards (Regional Board) through passage of the Porter-Cologne Water Quality Control Act (Porter-Cologne Act). The Porter-Cologne Act became effective on January 1, 1970.

Key sections of the Porter-Cologne Act upon which the State and Regional Boards base their authority to regulate the discharge or disposal of bittern in San Francisco Bay include Sections 13000, 13001, 13140 and 13142.

Section 13000 states, in part:

"The Legislature finds and declares that the people of the state have a primary interest in the conservation, control, and utilization of the water resources of the state, and that the quality of all the waters of the state shall be protected for use and enjoyment by the people of the state.

The Legislature further finds and declares that activities and factors which may affect the quality of the water of the state shall be regulated to attain the highest water quality which is reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible.

The Legislature further finds and declares that the health, safety and welfare of the people of the state requires that there be a state-wide program for the control of the quality of all waters of the state; that the state must be prepared to exercise its full power and jurisdiction to protect the quality of waters in the state from degradation originating inside or outside the boundaries of the state;"

Section 13001 states:

"It is the intent of the Legislature that the State Board and each regional board shall be the principal state agencies with primary responsibility for the coordination and control of water quality. The State Board and regional boards in exercising any power granted in this division shall conform to and implement the policies of this chapter and shall, at all times, coordinate their respective activities so as to achieve a unified and effective water quality control program in this state."

Section 13140 states:

> "The state board shall formulate and adopt state policy for water quality control. Such policy shall be adopted in accordance with the provisions of this article and shall be in conformity with the policies set forth in Chapter 1 (commencing with Section 13000)."

Section 13142 states, in part:

> "State policy for water quality control shall consist of all or any of the following:
>
> > "(c) Water quality control plans adopted by the state board for interstate or coastal waters or other waters of interregional or state-wide interest."

Pursuant to Sections 13140 and 13142, the State and Regional Boards have adopted the previously referred to water quality policy for the San Francisco Bay in 1967. The water quality objectives are set forth in Section III of the policy. Part A thereof comments on temperature, dissolved oxygen, toxicity and pH as follows:

"Temperature

No significant variation beyond present natural background levels (Notes A and B);

Toxic or Deleterious Substances

None present in concentrations which are deleterious to any of the beneficial water uses to be protected; none at levels which render aquatic life or wildlife unfit for human consumption (Note A);

Hydrogen Ion Concentration - pH

The pH shall remain within the limits of 7.0 and 8.5; when natural factors cause the pH to be less than 7.0, then further depression by controllable factors will be determined by the Regional Board on a case-by-case basis."

Two of the above objectives are footnoted as follows:

"A. The water quality objective will generally apply at the outer limit of the rising waste plume or beyond a limited dilution area as determined by the Regional Board on a case-by-case basis pursuant to the intent stated in the second paragraph of Section II-A. In prescribing requirements for a particular waste discharge, the Regional Board may specify receiving water quality limits, other than the water quality objective contained herein, to apply at control points at or near the outer edge of the rising waste plume if time of exposure and other considerations indicate that adequate protection of beneficial uses is assured.

B. A significant variation beyond present natural background levels will be any level of water quality which has an adverse and unreasonable effect on beneficial water uses or causes nuisance; present natural background levels are not known precisely and will be determined on a case-by-case basis."

As indicated previously, the aforementioned policy, including the referenced sections, has been approved by the Federal Government and has been adopted as Federal Water Quality standards in the Code of Federal Regulations pursuant to the Federal Water Pollution Act.

In addition to the previously cited policy for the San Francisco Bay, the State Board also has adopted a 1971 policy entitled

"Policy Regarding the Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California." Bittern is classified as an "elevated temperature waste," which is defined, in part, as "Liquid, solid, or gaseous material including thermal waste discharged at a temperature higher than the ambient temperature of receiving water."

"Elevated temperature wastes" are distinguished from "thermal wastes", which are defined in the policy as:

> "Cooling water and industrial process water used for the purpose of transporting waste heat."

San Francisco Bay is classified as an enclosed bay in the policy, and new discharges into such bays are required to comply with the following restriction:

> "Elevated temperature waste discharges shall comply with specific temperature limitations and other restrictions necessary to assure protection of beneficial uses. The maximum temperature of waste discharges shall not exceed the ambient temperature of the receiving waters by more than 20°F."

The foregoing policy was recently approved by the Environmental Protection Agency.

California Regional Water Quality Control Board, San Francisco Bay Region

The Regional Board, in concert with the State Board, is charged with the responsibility of implementing the foregoing policies as well as the enforcement of many laws and specific sections of the Porter-Cologne Act.

Sections 13260-13269 prescribe the procedures whereby proposed waste discharges are reviewed and approved by the Regional Boards. This report constitutes the report on the proposed discharge of bittern as required under Section 13260. Under authority granted to it under these and other sections of the Porter-Cologne Act, the Regional Board requires that all reports on waste discharge include a determination of the present quality of the receiving waters and evaluation of the potential effects of the waste on the water quality. This requirement is met by this report, and in particular the material presented in Chapters III through VI. Chapter VI contains comments on the environmental impact of the discharge on the receiving waters.

Reference has been made previously to the 1967 Federal and State water quality standards adopted for San Francisco Bay.

That policy contains a reference to Resolution No. 803 of the Regional Water Quality Control Board, dated December 15, 1966, setting forth further policy of the Regional Board with respect to the public health and concerning the beneficial uses to be protected. With respect to the proposed discharge of bittern by the Leslie Salt Company, parts XIV, XV, XVI, XVIII, XIX, and XXII of Resolution No. 803 appear to have particular application. A copy of Resolution No. 803 is reproduced in Appendix D.

Part XIV sets forth the beneficial uses of the waters to be protected, and recognizes waste dispersion and assimilation as a use of tidal waters. However, part XV states that it is the intention of the Regional Board to protect the certain beneficial uses of such waters, including "fishing, hunting, fish and wildlife propogation and sustenance" and that it will

> "permit reasonable and necessary dispersion and assimilation of wastes <u>to the extent that it will not objectively or unreasonably interfere with the beneficial uses to be protected</u>." (emphasis added)

Part XVI provides that Resolution No. 803 shall be used by the staff of the Regional Board as a guide in the development of waste discharge requirements. Part XVIII states that the Regional Board:

> "A. Considers that dilution areas are not fixed and are subject to constant review with the ultimate

objective of complete elimination or substantial reduction in their size and number as comprehensive waste disposal plans are promulgated or existing waste discharge requirements are reviewed.

B. Encourages waste dischargers to investigate the advantages of deepwater outfalls removed from areas of intensive onshore and/or near-shore recreational activities."

Part XIX provides that acts of the Regional Board with respect to Resolution No. 803 shall be consistent with Section 13000.2 of the California Water Code which relates to the general policy of the State of California to protect the quality of its waters. Finally, Part XXII provides for the possible future revision of the policy enunciated in Resolution No. 803, as additional information becomes available and as demands for beneficial uses change.

California Department of Fish and Game

While the Legislature has stated its intent that the State and Regional Boards "shall be the principal state agencies with primary responsibility for coordination and control of water quality," it has also charged the Department of Fish and Game with significant responsibilities relating to the preservation and enhancement of California fish and wildlife resources.

Section 1600 of the California Fish and Game Code declares, in part that:

> "The protection and conservation of the fish and wildlife resources of this State are hereby declared to be of the utmost public interest."

Section 5650 states, in part that:

> "It is unlawful to deposit in, permit to pass into, or place where it can pass into the waters of the State... any substance or material deleterious to fish, plant life, or bud life."

Section 5651 states:

> "Whenever it is determined by the Department that a continuing and chronic condition of pollution exists, the department shall report such condition and to the appropriate regional water quality control board, and shall cooperate with and act through such board in obtaining correction in accordance with any laws administered by such board for control of practicies of sewage and industrial waste disposal."

In the development of policy regarding water quality matters affecting California's fish and wildlife resources, and particularly when setting specific waste discharge standards, the State and Regional Boards are to give careful consideration to the views and recommendations of the Department of Fish and Game.

During its investigation leading to the preparation of this report, CDM Inc., ENVIRONMENTAL ENGINEERS has conferred with representatives of the Department of Fish and Game to determine areas of particular concern to the Department related to the proposed discharge. The Department has indicated particular concern over the effect of the proposed discharge on the striped bass fishery in San Francisco Bay, and has cited potential problems of toxicity and pH that could have an adverse effect on the benthic and pelagic aquatic organisms. Special concern has been expressed over the potential extent of the zone of acute toxicity. These areas of concern have been given special study and consideration during the investigation.

III. CHARACTERISTICS OF RECEIVING WATERS

An analysis of the dominant physical and chemical characteristics of the receiving waters of San Francisco Bay in the vicinity of Dumbarton Bridge and of the bittern is required in order to select the proper location and design of the proposed waste discharge facilities. Particular reference herein will be made to those characteristics of significance to the beneficial uses of the Bay which would be influenced by the proposed discharge.

Physical Characteristics

In the vicinity of Dumbarton Bridge, San Francisco Bay narrows to a width of approximately 6,200 feet (1,880 meters) at mean higher-high water (MHHW) and has a maximum depth of about 40 feet (12 meters). At mean lower-low water (MLLW) the width narrows to approximately 3,300 feet (1,000 meters).

Two high and two low waters occur each day with typical diurnal variations in both their magnitude and timing of occurrence. The mean tide range at the Golden Gate is about four feet, whereas at Dumbarton Bridge the tidal movement virtually produces a standing wave and the mean tidal range is nearly seven feet. The maximum tidal fluctuation at Dumbarton Bridge between MLLW and MHHW is about nine and one-half feet.

Current velocity, temperature, salinity and specific gravity measurements have been made in the vicinity of Dumbarton Bridge on both a continuous and intermittent basis by at least three agencies of the Federal Government, including the National Ocean Survey (formerly the Coast and Geodetic Survey), the Corps of Engineers and the Geological Survey. These measurements have been conducted over a sufficient period of time and to a degree of detail more than adequate to define the probable variation in these parameters during the proposed period of discharge.

Tidal Current Velocities

The Coast and Geodetic Survey has made a number of velocity measurements at Dumbarton Bridge over many tidal cycles sufficient to permit the determination of the velocity profile throughout the full depth of the water column. The Corps of Engineers has also made selected velocity measurements over an approximate average tidal cycle during verification studies for its San Francisco Bay hydraulic model. Results of these measurements indicate that tidal velocities at Dumbarton Bridge are more uniformly distributed through the water column than in other portions of the Bay, and are not significantly influenced by natural stream inflow during the winter months.

Presented in Table 2 are typical velocity measurements taken from unpublished records of the Coast and Geodetic Survey during three observations of maximum ebb currents during the period

May 11-15, 1953, at a station located very near Dumbarton Bridge. From the tabulated data, which are representative of a number of observations made over a period of several years, it appears that the maximum ebb current near the bottom varies from about 1.4 to 1.8 knots (2.4 to 3.0 feet per second) without significant variation in the vertical profile.

TABLE 2

VARIATION IN MAXIMUM EBB TIDE
CURRENT VELOCITIES NEAR DUMBARTON BRIDGE

	Date of observation					
	5/11/53		5/12/53		5/14/53	
Depth, ft.	Knots	Ft. per sec.	Knots	Ft. per sec.	Knots	Ft. per sec.
8	1.7	2.9	1.7	2.9	1.8	3.0
20	1.6	2.7	1.6	2.7	1.5	2.5
35	1.4	2.4	1.5	2.5	1.8	3.0

The Coast and Geodetic Survey has also published tidal current information for San Francisco Bay at Dumbarton Bridge. While these data are primarily related to the shallower depths (2-5 meters) because of the navigation purpose they serve, they do give information on the duration of tidal cycles, as shown in Table 3.

TABLE 3

TIMING, DIRECTION AND DURATION OF TIDAL VELOCITIES AT DUMBARTON BRIDGE

Average surface velocity, in knots	Direction	Time
1.1	South	2 hours before maximum flood
1.7	South	1 hour before maximum flood
1.8	South	@ maximum flood
1.5	South	1 hour after maximum flood
0.9	South	2 hours after maximum flood
Slack	-	3 hours after maximum flood
1.0	North	2 hours before maximum ebb
1.8	North	1 hour before maximum ebb
2.0	North	@ maximum ebb
1.7	North	1 hour after maximum ebb
1.0	North	2 hours after maximum ebb
0.3	North	3 hours after maximum ebb

Salinity and Temperatures

Several agencies have made salinity and temperature measurements at various times throughout San Francisco Bay, the most recent and comprehensive of which were made by the Geological Survey in 1969 and 1970.

Presented in Table 4 are the results of two series of such measurements made by the Geological Survey at Dumbarton Bridge during January and February of 1969.

TABLE 4

VARIATION IN TEMPERATURES AND SALINITY
AT DUMBARTON BRIDGE

Depth in meters		Date of observation 1/31/69	2/7/69
0	T 1/	9.25	10.46
	S 2/	14.42	12.51
1.5	T	9.11	9.91
	S	14.55	12.61
3	T	8.97	9.89
	S	14.49	12.78
6	T	9.10	9.84
	S	14.49	12.82
9	T	9.37	9.86
	S	14.49	12.82
12	T	9.40	9.84
	S	14.49	12.84

1/ Temperature in °C
2/ Salinity in o/oo (Grams of salt per 1,000 grams of seawater)

Subsequent measurements made by the Geological Survey in 1970 at the Dumbarton Bridge and other stations in the Bay, as well as numerous other intermittent observations by other agencies, suggest that the measurements presented in Table 4 are typical of ambient water conditions in the Bay at that location.

Specific Gravity

The specific gravity of the waters of San Francisco Bay depends on its temperature as well as the amount of soluble material held in solution. The portions of the Bay closer to fresh water entry points will therefore tend to have average specific gravities somewhat lower than those portions closer to the Golden Gate. Also, the density of the warmer, shallow waters, particularly in the intertidal zone, will tend to have a lower specific gravity than waters in the deeper zones. Except for the localized effects of the foregoing factors, the waters of the Bay generally have lower specific gravities in the summer than in the winter.

In addition to scattered observations which have been made by a number of agencies, the Coast and Geodetic Survey publishes specific gravity observations for nine stations in San Francisco Bay, including one at Dumbarton Bridge.

All of these data indicate that the ambient specific gravity of the Bay water in the zone of proposed discharge varies from about 1.015 to 1.026 during the proposed period of discharge.

Chemical Characteristics

Considerable study has been given to water quality problems in the San Francisco Bay as part of a number of Federal, State and local investigations. Results of these studies have indicated that in order to protect the present and projected beneficial uses of the Bay as set forth in the State's water quality policy, substantial improvements will be required in the present methods of treatment and disposal of certain liquid wastes. Other influences on the quality of the waters of the Bay include upstream water diversions, hydrologic conditions, the physical configuration of the Bay, as well as changes in such configuration resulting from dredging and filling.

The California Fish and Wildlife Plan states that the most damaging of these influences with respect to fish and wildlife impact include existing and projected upstream diversion; certain waste discharges such as oil, pesticides, heavy metals and other substances which either kill fish directly, or make flesh unsuitable for human consumption; and the additions of heat, turbidity and nutrient loadings which may make the receiving waters unsuitable for fish and fish food organisms.

The present quality of the waters of San Francisco Bay reflect all of these as well as a host of other natural and man-made influences. In the next chapter a comparison will be made between the actual chemical quality of the bittern proposed to be discharged with the corresponding chemical quality of the Bay. In connection with the present study, the Ray W. Hawksley Company has analyzed a sample of Bay water taken from the vicinity of the proposed discharge on February 16, 1972, and the results are presented in Table 5.

Data tabulated in Table 5 compare generally with similar data appearing in several Federal and State reports and is considered to reflect ambient conditions during a typical winter period under relatively dry hydrologic conditions. Results of other analyses which have been published, particularly reflecting conditions during or after periods of greater surface inflow, indicate that many of the constituents under such conditions have lower concentrations than those shown in Table 5. This reflects the importance of the flushing and consumptive use processes in the south Bay area.

TABLE 5

CHEMICAL ANALYSIS OF
SAN FRANCISCO BAY WATER
IN VICINITY OF DUMBARTON BRIDGE,
FEBRUARY 16, 1972

Constituent	Concentration
pH	8.1
Total Solids, ppm	30631
Total Volatile Solids, ppm	5488
Total Suspended Solids, ppm	44
Total Dissolved Solids, ppm	30587
Alkalinity as $CaCO_3$, ppm	194
BOD, ppm	1.2
COD, ppm	255
Ammonia as N, ppm	0.06
Kjeldahl Nitrogen Total, ppm	1.10
Nitrate as N, ppm	0.72
Phosphorus Total as P, ppm	0.41
Chloride, ppm	1700
Cyanide, ppm	<0.04
Fluoride, ppm	1.21
Phenols, ppb	<6
Sulfate as S, ppm	2400
Sulfide as S, ppm	<2
TOC, ppm	18.5
Aluminum, ppb	200
Arsenic, ppb	<10
Cadmium, ppb	<20
Calcium, ppm	380
Chromium, ppb	<20
Iron, ppb	20
Lead, ppb	<20
Mercury, ppb	<1
Sodium, ppm	7500
Titanium, ppb	<20
Zinc, ppb	30

All tests by Standard Methods 13th Edition except Hg, Ti by WQO

IV. CHARACTERISTICS OF BITTERN

This chapter presents an analysis of the characteristics of the bittern and a selective comparison thereof with similar characteristics of the receiving waters having an influence on the location and design of the proposed waste discharge facilities. A discussion of toxicity considerations is also presented.

Physical and Chemical Characteristics

A general description of the bittern production process and some of the changes in the properties of the bay water as it passes through the salt reduction process are presented in Chapter I. Proper design of the waste discharge system will require consideration of the volume as well as the physical and chemical properties of the bittern.

As previously indicated, large volumes of bay water must be evaporated in order to produce crude salt. In order to produce one million tons of salt, about 38.3 million tons of bay water containing 0.22 pounds of salt per gallon are required. The reduction process produces a million tons of bittern for every million tons of salt produced, during which about 36 million tons, or roughly 8.6 billion gallons of water are evaporated to the atmosphere.

Based on projected crude salt production at its three south bay plants, Leslie Salt Company proposes to dispose of a total of 201 million gallons of bittern per year (mgy) into the Bay near Dumbarton Bridge, including about 126 mgy from the east bay plants at Newark and Baumberg, and 75 mgy from the west bay plant at Redwood City.

In order to obtain maximum dispersion benefits from outgoing currents, as will be discussed in the latter portion of this chapter, it is proposed that the bittern be discharged only during the six colder months of the year, when tidal flows are greater, and for only about two and one-half hours of each tidal cycle at the maximum flow of the ebb tide. On this basis, the design flow is ~5.5 mgd.

As a means of insuring the achievement of the desired concentration of bittern immediately upon discharge, it is proposed that the bittern be diluted with bay water in a 1:1 proportion prior to discharge. As a result, the total volume of diluted bittern to be delivered through the discharge facilities will be 402 mgy or approximately 1,234 acre-feet per year.

During the portion of the year when the discharge facility would be operable, the bittern in the storage ponds would have a specific gravity of about 1.283 (32°Bé). The Bay water normally has a specific gravity of from 1.015 to 1.026. Therefore, when the bittern is mixed with an equal volume of bay water, the resulting liquid delivered through the discharge facilities will have a specific gravity ranging from 1.152 to 1.158.

Prior to initial dilution, the bittern would have an average temperature of about 16°C. Both the bittern and bay temperatures fluctuate considerably throughout the proposed discharge period. However, analysis of available records indicate that the temperature of the undiluted bittern would not exceed the ambient bay water temperature at the point of discharge by more than 3° to 4°C. Because bay water to be used for diluting the bittern would be drawn from the shallower tidal flats rather than the deeper zones, it is estimated that the diluted bittern will probably exceed the ambient bay temperatures by only 2° to 3° C. At these levels, the discharge would be well within the elevated waste discharge standards of both the State Water Resources Control Board and the Environmental Protection Agency.

At a specific gravity of 32° Bé, a typical bittern sample will have a pH varying from 7.0 to 8.0, and will contain the following magnesium, sodium and potassium salts:

Constituent	Percent by Weight
$MgCl_2$	11.8
$MgSO_4$	6.7
NaCl	6.7
KCl	1.8
KBr	0.2
$MgBr_2$	Trace

As part of the present study, an analysis of typical bittern, collected on February 16, 1972 and diluted with bay water at a 1:1 ratio, was submitted to the Ray W. Hawksley Company for analysis, so that a comparison could be made with bay water. Such a comparison is presented in Table 6 and is representative of actual differences which may be expected between the waste material being discharged and the ambient receiving waters. Data presented in Table 6 for bay water are identical to those presented earlier in Table 5.

During the salt reduction process, a series of significant changes take place in the plant and animal life found in the intake water from the Bay. Fish as well as most of the micro-organisms found in the Bay are present in the first series of evaporating ponds. In the next three systems of ponds, several forms of life start to die off and new forms begin to appear. In the fifth pond system, the specific gravity has reached 1.074 (10° Bé) and no fish remain. However, brine shrimp (Artemia salina) and yellow algae (Dunaliella viridi) are found and appear to thrive on the dead organic matter. In the seventh and eighth systems of ponds, the shrimp and algae are still quite viable and contribute to the formation of certain calcium salts. Red chromogerin bacteria along with other new organisms begin to form in the eighth pond, where the specific gravity of the brine has reached 1.160 (20° Bé). The red bacteria also provide a portion of the food supply for the shrimp in this pond. In

TABLE 6

CHEMICAL ANALYSIS OF
BAY WATER AND BITTERN
FEBRUARY 16, 1972

Constituent	Concentration: Bay Water	Concentration: Bittern 1:1
pH	8.1	7.8
Total Solids, ppm	30631	241550
Total Volatile Solids, ppm	5488	86600
Total Suspended Solids, ppm	44	1760
Total Dissolved Solids, ppm	30587	239790
Alkalinity as $CaCO_3$, ppm	194	2800
B.O.D., ppm	1.2	198
C.O.D., ppm	225	6350
Ammonia as N, ppm	0.06	0.702
Kjeldahl Nitrogen Total, ppm	1.10	32.610
Nitrate as N, ppm	0.72	37.50
Phosphorus Total as P, ppm	0.41	0.22
Chloride, ppm	17000	158000
Cyanide, ppm	<0.04	<0.04
Fluoride, ppm	1.21	74.90
Phenols, ppb	<6	64.10
Sulfate as S, ppm	2400	21000
Sulfide as S, ppm	<2	<2
TOC, ppm	18.5	900
Aluminum, ppb	200	2500
Arsenic, ppb	<10	40
Cadmium, ppb	<20	<20
Calcium, ppm	380	450
Chromium, ppb	<20	<20
Iron, ppb	20	6500
Lead, ppb	<20	<20
Mercury, ppb	<1	<1
Sodium, ppm	7500	5500
Titanium, ppb	<20	<20
Zinc, ppb	30	190

All tests by Standard Methods 13th Edition except Hg, Ti by WQO the ninth pond system, the shrimp and algae start to die off but the red bacteria continue to thrive until the bittern forms. The bacteria thereupon start to die and settle to the bottom of the ponds.

As a result of the decaying organic matter, the bittern contains relatively high COD and BOD, no dissolved oxygen, and relatively high turbidity as shown in Table 7.

TABLE 7

SELECTED CHARACTERISTICS OF BITTERN
AT THREE SOUTH BAY PLANTS

Plant	COD ppm	DO ppm	BOD ppm	Turbidity: JTU	pH	°Bé @ 16°C
Newark	4,250	0	140	180	7.2	32.4
Baumberg	5,080	0	185	240	7.0	33.6
Redwood City	3,250	0	135	80	7.0	32.7

Table 7 reveals that the raw bittern meets the standard for pH established previously by Regional Water Quality Control Board in Resolution No. 70-23 adopted on March 26, 1970. Table 7 also suggests that the dissolved oxygen minimum limit of 5.0 mg/l established in Resolution No. 70-23 cannot be met without the dilution and dispersion technique recommended herein. The concentrations of COD and BOD for the full strength of bittern shown in Table 7 may be compared with similar concentrations for bittern presented in Table 6 illustrating the great variations which may be expected with these constituents, probably depending in part upon the length of storage of the saturated brine in the final two systems of ponds.

Toxicity Considerations

The California Department of Fish and Game has evidenced great concern over the discharge of any toxic substances into marine and estuarine environments because of their potentially deleterious effects on both plant and animal life. These effects may be both short-term and long-range.

Of immediate concern is the direct toxic action toward a given species, commonly measured within a period of 96 hours or less and referred to as "direct" or "acute" toxicity. Of longer range concern, though by no means less significant, is the toxic action toward a species or its food chain, which may take place over periods of several weeks, months or years. The long range deleterious effects of such actions are known as "chronic" toxicity.

Experimental data on toxicity are reported in terms which can be conveniently measured during laboratory tests. Most frequently in bioassay work, the term TL_m (tolerance limit, median) is used to designate the concentration of a toxic substance required to kill 50 percent of the tested organisms. Occasionally, the term MLD (minimum lethal dose) is used which refers to the concentration required to kill one or more of the tested organisms.

The toxicity of bittern toward plant and animal life is a function of both time and concentration. For higher concentrations of bittern, its toxicity increases with continued exposure. As the concentration is reduced, a level is reached where the toxicity of the diluted bittern is not measurable or discernible from bay water, and the solution is neither acutely nor chronically toxic.

While many species of plant and animal life can survive for short periods within highly toxic environments with no observable deleterious effects, changes in growth rates, physiology, behavior patterns, reproduction capability and other vital functions may occur. Concern over these long-range effects, during their difficulty of measurement and the lack of sufficient published information on the subject, has caused regulatory agencies to adopt a somewhat cautious attitude with respect to both water quality standards and waste discharge requirements.

The California Department of Fish and Game has recommended that the discharge of bittern be prohibited in concentrations toxic or deleterious to fish and other aquatic life. By Resolution No. 70-23, dated March 20, 1970, the California Regional Water Quality Control Board required that the waste bittern shall meet the following quality limits in any representative 24-hour composite sample:

Toxicity: Survival of test fishes in 96-hour bioassays of the waste as discharged

Any sample	75%
Average of any three or more consecutive samples collected during any 21 or more days	90%

Laboratory tests performed by the Ray W. Hawksley Company for the Leslie Salt Company have indicated that the bittern has a 96-hour TL_m of between 1.4 to 2.0 percent as shown following:

Report Date	Sample	96-Hour TL_m
July 17, 1970	Plant No. 2	2.0%
July 27, 1970	Plant No. 2	1.75%
September 15, 1970	Composite	1.50%
September 25, 1970	Composite	1.4%
September 25, 1970	Composite	1.75%
October 4, 1970	Composite	1.4%

Tests performed on bittern samples from Newark, Redwood City and Baumberg ponds further indicate that an average dilution of 100:1 will be required to maintain 100 percent survival of test fishes at 96 hours, as shown in Table 8.

TABLE 8

DILUTION REQUIREMENTS TO MAINTAIN 100 PERCENT SURVIVAL OF TEST FISHES

Date	Sample	Bay water dilution required to meet 100% survival test
10/13/70	1. Bay water, deep channel at Dumbarton Bridge, at high tide	None
	2. Newark bittern	80:1
	3. Bay water, deep channel off Redwood City at high tide	None
	4. Redwood City bittern	100:1
	5. Baumberg bittern	125:1
10/26/70	1. Bay water, deep channel at Dumbarton Bridge, at low tide	None
	2. Newark bittern	100:1
	3. Bay water, deep channel off Redwood City, at low tide	None
	4. Redwood City bittern	100:1
	5. Baumberg bittern	125:1
10/23/70	1. Bay water, deep channel at Dumbarton Bridge at high tide	None
	2. Newark bittern	100:1
	3. Bay water, deep channel off Redwood City at high tide	None
	4. Redwood City bittern	80:1
	5. Baumberg bittern	100:1

Other laboratory tests indicate, as shown in Table 9, that the toxicity of the bittern is unrelated to the high COD and BOD levels. Thus, laboratory tests appear to discount the overall significance of the environmental impact of these two constituents.

TABLE 9

EFFECT OF COD AND BOD
ON FISH SURVIVAL TESTS
OF BITTERN

Sample	COD ppm	BOD ppm	Dilution required to meet 100% survival test
Bittern	4,250	140	100:1
Bittern with organic matter destroyed	0	0	100:1
Bittern prepared by concentrating Bay water in laboratory	4,950	260	100:1

Unfortunately, it is difficult to relate the results of such studies to actual conditions in the field because the constant interaction of all of the natural parameters cannot be reproduced in the laboratory. Varying field conditions produce constant changes in the horizontal and vertical distribution and number of plankton. These changes are probably due to many biochemical mechanisms, which at times will encourage the reproduction of certain species under conditions that are totally imcompatible with the survival of others.

Another problem which must be considered in evaluating the potential toxic effects of a particular substance on microscopic plant and animal life, is the fact that fish and other higher forms of life, as well as many species of the benthic community can and do feed upon or otherwise ingest such microscopic life, whether it is living or dead, with no apparent difference in its nutritional value. As a result, there is no substantial evidence, nor can it be inferred, that the temporary injury or even the destruction of plankton in a localized area for limited periods of time would necessarily have a long-term or even a significant effect on the life processes of other members of the biomass.

As part of its ongoing research on problems in connection with the disposal of effluents from desalination plants, the Federal Office of Saline Water (OSW) has investigated the ecological effects of the disposal of saline wastes on marine environments. Results of these and other studies indicate that the salinity parameter is of particular importance in controlling the distribution and numbers of plankton.

Most animal life in San Francisco Bay is dependent, either directly or indirectly, on the photosynthetic activity of unicellular algae. Laboratory studies on these algae have shown that most species are tolerant of a wide range of salinities, although they seem to prefer lower salinities. Some algae, termed halophytes, can tolerate relatively high ranges of salinity, but such organisms are not characteristic of the normal marine environment. It appears that most phytoplankton of neretic or oceanic distribution can tolerate a somewhat broad range of salinities, but their growth rates drop markedly as the salinity rises above 40 o/oo.

The OSW studies involved examination of several parameters of marine water concurrently with variations in salinity, and they demonstrate that salinity is one of the most important factors affecting the growth and survival of marine biosystems. However, the studies show that salinity is of lesser importance than temperature in regulating the seasonal occurrence and distribution of plankton.

V. DESIGN AND OPERATION OF DIFFUSER FACILITIES

The design of the proposed diffuser facilities is based on a preliminary theoretical analysis and subsequent hydraulic model studies of the diffuser performance. The laboratory experiments confirmed the validity of the preliminary design assumptions and demonstrated a high level of performance which may be expected from the prototype facility.

Theoretical Design

The total volume of bittern to be discharged to the Bay, based on estimates of production provided by Leslie Salt Company, is 200 mgy at a specific gravity of 1.283 (32°Bé). In order to obtain maximum benefit from the outgoing currents, it is planned that the bittern would be discharged only during the six colder months of the year, when fresh water inflow to the Bay is likely to be greater, and for only about two and one-half hours of each tidal cycle at the maximum flow of the ebb tide. On this basis the design flow would be 5.5 mgd.

Examination of the cross-section of San Francisco Bay at Dumbarton Bridge at MLLW reveals that the diffuser should be less than about 1,100 feet long in order to avoid influencing the shallow waters where most of the fish migrations and feeding occur.

Studies by Leslie Salt Company indicate that a dilution of about 100:1 is required for 100 percent survival of test fish in bittern. The diffuser should therefore be designed to obtain a dilution of 100:1 or better before the plume strikes the bottom of the Bay.

Various possible angles were considered for the diffuser ports, ranging from 45 to 90 degrees from the horizontal, but it was felt that a final decision would have to await the results of laboratory tests. Studies for the OSW have shown that the greatest dilution for non-buoyant jets can be obtained by setting the ports at an angle of about 60 degrees up from the horizontal. The resulting dilution at the peak of the trajectory can be approximated by the formula:

$$S = Fr/1.8 \qquad (1)$$

in which S is the dilution and Fr is the densimetric Froude number, defined as:

$$Fr = \frac{V}{\sqrt{\frac{\rho_o - \rho_e}{\rho_e} gd}} \qquad (2)$$

In equation (2),

V = initial jet velocity

ρ_o = specific gravity of bittern, 1.28

ρ_e = specific gravity of bay water, 1.03

g = acceleration due to gravity

d = port diameter

Dilution when the jet returns to the same elevation as the jet discharge for such jets is about three times the dilution at the apogee. Hence, the dilution by the time the jet returns to the bay bottom would be about Fr/0.6. Because the specific gravity of bittern is substantially greater than the liquids on which studies have been conducted, a safety factor of about 50 percent was employed in the diffuser design. It was therefore assumed that the terminal dilution would equal the Froude number.

If bittern is discharged into the Bay directly from storage, the best diffuser would be 920 feet long and have 3/8-inch ports, four feet apart. Larger ports would require a very high velocity for dilution and cavitation would result. Smaller ports would require a diffuser longer than the width of the Bay. Since ports as small as 3/8 inch could present a possible problem with clogging, the discharge of undiluted bittern was not considered advisable. Accordingly, the design discharge was revised to 11 mgd by diluting the brine 1:1 with bay water prior to discharge.

In order to avoid cavitation and the possibility of negative pressures for the range of depths found in San Francisco Bay, it was determined that the velocity of the discharging bittern diluted with an equal volume of bay water would be 30 feet per second. The one-inch diameter ports were therefore selected, requiring a diffuser 625 feet long with ports spaced on six-foot centers. In order to maintain reasonable velocity and head levels, the diffuser pipeline should be 24 inches in diameter.

Hydraulic Model Studies

Hydraulic model studies were conducted to test the foregoing theoretical design at the hydraulic laboratory of a nearby academic institution. The experiments were conducted by Dr. E. J. List with staff assistance by CDM Inc. personnel. Results of the entire model study are included in Appendix A.

In order to be assured of maximum diffusion and to minimize the environmental impact, the model studies were conducted over a range of tidal velocities equal to and less than those expected to be encountered under actual operating conditions. Since the maximum ebb tide velocity at the bay bottom was found to be about 1.8 knots, or 3.0 feet per second, one experiment was conducted at that equivalent velocity.

It is proposed that the diffuser will discharge only for a period of two and one-half hours at the peak period of ebb tide flow. Hence, the diffuser would be operable over the span of time between one and one-quarter hours before and after maximum ebb tide. In order to test the safety factor available under such a condition, a second experiment was conducted at the equivalent velocity that would be expected 15 minutes before and after the proposed discharge, or one and one-half hours before and after maximum ebb tide. At those points on the tidal cycle the actual velocity would be about 0.7 knots or approximately 1.2 feet per second.

An additional experiment was conducted at a point in time equivalent to two hours before and after maximum ebb tide when the tidal velocity would be about 0.5 knots or approximately 0.8 feet per second. Such a test would be indicative of conditions 45 minutes before the start and after the conclusion of the prototype discharge.

Additional experiments were conducted to determine the effect of different jet angles as well as to confirm the probable results of a jet discharge during slack water.

Results of the hydraulic model experiments are depicted in photographic and chart form in the figures accompanying Appendix A, and confirm the reasonableness and efficacy of the proposed design.

The first experiment, conducted at a velocity equivalent to that which may be expected at maximum ebb tide (3.0 feet per second), clearly shows that the jet plume never reaches the bottom and that dilution levels substantially higher than the minimum requirement of 100:1 will be achieved at about two meters longitudinally and about 0.8 meters vertically from the point of discharge. The plume at that dilution would never achieve a vertical thickness and horizontal width exceeding 0.2 meters (6 inches) and 0.8 meters, respectively. At no time would the bittern dilution near the bay bottom be less than 400:1, suggesting that the benthic organisms may not even be able to discern the existence of the discharge.

The second experiment, though conducted at an equivalent tidal velocity somewhat lower than the minimum which would exist under prototype conditions, also shows a jet configuration somewhat similar to that in the first experiment. The 100:1 dilution contour extended no greater than about 2.4 meters longitudinally and about 1.3 meters vertically from the point of discharge, and never achieved a vertical thickness or horizontal width greater than 0.4 meters (12 inches) and 1.2 meters, respectively. It was also determined that the minimum bottom dilution would be at least 480:1.

In the third experiment, the jet can be seen to spread quickly over the bottom directly after impact. Notwithstanding, the 100:1 dilution plume would still not extend more than about three meters longitudinally and 1.7 meters vertically from the point of discharge, and would have a vertical thickness and horizontal width of about 0.5 meters (20 inches) and 1.8 meters, respectively. A bottom region of at least 130 square feet would be exposed to a dilution of between 200:1 and 400:1.

Results of the hydraulic model experiments confirmed the validity of the 60 degree jet angle as well as the other basic design assumptions employed at the theoretical design stage. The experiments show that there should be no problem whatsoever in achieving a bittern dilution of 200:1 or greater by operating the diffuser during the period of time between two hours before and two hours after maximum ebb tide. The diffuser is only proposed to be operated between one and one-quarter hours before and after maximum ebb tide. The results also show that a 400:1 dilution level can be maintained when the diffuser is operated during the interval of time between one and one-half hours before and after maximum ebb tide. Finally, the results show that a 100:1 dilution level can be maintained from slack water to slack water.

The conservative nature of the proposed design is thus clearly evident. Since the jet plume would never rise to a height of more than three meters under the worst possible condition, at least eight meters of undisturbed water would exist above the diffuser at all times. Under proposed operating conditions, the cross-sectional area affected by the jet plumes from all of the ports would only constitute about one percent of the total cross-sectional area of the Bay at Dumbarton Bridge at MHHW.

Construction Costs

Estimates of construction costs were made for two alternatives. The first alternative, not shown on Figure 1, is for constructing quirement of 100:1 will be achieved at about two meters longitudinally and about 0.8 meters vertically from the point of discharge. The plume at that dilution would never achieve a vertical thickness and horizontal width exceeding 0.2 meters (6 inches) and 0.8 meters, respectively. At no time would the bittern dilution near the bay bottom be less than 400:1, suggesting that the benthic organisms may not even be able to discern the existence of the discharge.

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new pumping facilities and a pipeline parallel to the one that is now installed near Dumbarton Bridge. The existing line is depicted on Figure 1. The new pipe would have a diameter of 24 inches and be a total of 3,300 feet long. It is estimated that the cost for constructing this line would be about $300,000, including engineering and contingencies.

The second alternative, as depicted on Figure 1, involves the use of the existing pipe across the Bay and the connection of the diffuser to this line. This alternative would require replacement of the existing pump. Total construction costs, including engineering and contingencies, would be about $106,000. This installation would not interfere with the present use of this line by Leslie Salt Company since it is only used in the summer. This alternative is recommended because it is the least costly and makes more efficient use of existing facilities. A summary of the capital costs of this alternative is presented in Table 10.

Operation and Maintenance

The foregoing construction cost estimate includes the provision of a manually-operated valve at the entrance to the diffuser. Operation of this valve would require the services of a diver twice a year. This would provide the opportunity for a visual inspection of the discharge ports as well as bottom conditions in the Bay in the vicinity of the diffuser and would greatly augment the effectiveness of the monitoring program to be prescribed by the California Regional Water Quality Control

TABLE 10

CAPITAL COSTS OF PROPOSED
WASTE DISCHARGE FACILITIES

Item	Estimated capital cost 1/
Diffuser pipeline, 625 ft. long, 24-inch diameter, cement mortar and somastic-coated steel pipe	$ 55,500
Pump and motor	13,000
Flow meter	7,000
Butterfly valves, 2 @ $2,500 each	5,000
Diffuser ports, 104 @ $24 each	2,500
Underwater connection to existing pipeline	2,000
Subtotal	$ 85,000
Engineering and contingencies, 25 percent	21,000
Total	$106,000

1/ Based on assumed construction in September, 1972 (ENR Construction Cost Index of 1970).

Board. Maintenance and operational problems for an intermittent discharge should be minimal if an automatic timer is used to operate the pumps in sequence with tidal cycles. The timer should be checked and adjusted from time to time to reflect changes in tide schedules.

It is estimated that annual operating costs for the proposed discharge operation will be about $3,600, distributed as follows:

Power costs	$ 2,100
Diver to open and close valve	500
Monitoring costs (analyses once a month for six months)	600
Miscellaneous	400
Total	$ 3,600

VI. IMPACT ON THE MARINE ENVIRONMENT

Section 13260 of the California Water Code requires that a waste discharge report be filed with every application for a new waste discharge, or for a material change in the place or methods of disposal of an industrial waste. This report constitutes a detailed report in support of the application of the Leslie Salt Company for a revision of waste discharge standards established for the Company on April 8, 1970, by the California Regional Water Quality Control Board, San Francisco Bay Region, pursuant to Resolution No. 70-23. Design criteria for the proposed discharge, and other information required for action by the Regional Board are presented in Chapter V.

This chapter contains a discussion of the probable impact on the receiving waters of the proposed discharge and covers the subject matter specified to be discussed in environmental impact statements required under the National Environmental Policy Act of 1969. With this information, the report will also serve as documentation and support for the application of the Leslie Salt Company for a waste discharge permit from the United States Army Corps of Engineers pursuant to the Rivers and Harbors Act of 1899.

Marine Life in the Dumbarton Channel Area

The Department of Fish and Game has published a number of reports and periodicals over the years describing the marine life of San

Francisco Bay in general, and several of those describe biologic life in the vicinity of Dumbarton Bridge. In addition, reports prepared by the Coast and Geodetic Survey and the University of California provide excellent resource information on physical and chemical aspects of the south San Francisco Bay area. From these reports a number of conclusions can be drawn respecting the probable impact of the proposed discharge of dilute bittern on the marine environment.

During the investigation leading to the preparation of this report, conferences have been held with staff representatives of the California Regional Water Quality Control Board as well as the Department of Fish and Game in an effort to identify the fish species and other marine organisms of particular concern. Results of these conferences and a review of the extensive literature on the subject suggest that maintenance of the striped bass fishery and the important elements of its food chain will be of primary concern. A list of publications reviewed in this regard is set forth in the bibliography forming Appendix B.

Striped Bass Fishery

The Department of Fish and Game has expressed special concern over the striped bass fishery in San Francisco Bay and has devoted considerable research into means for maintenance and enhancement of this important sport fishery. An excellent picture of the life history and the spawning and migratory habits of the striped bass can be obtained from several publications of the Department.

Although anadromous, striped bass are found in San Francisco Bay almost any month. They generally spawn in late spring and early summer. A fall migration also occurs in September and October. Investigators are unanimous in their findings that the migrations of the striped bass are directly related to fresh water inflows to the Bay, to the spawning activity and because of the importance of these flows, the sustenance of the eggs. Most of the historic catch data show the predominance of striped bass in the upper San Francisco Bay, San Pablo Bay, Suisun Bay throughout many miles of the lower Sacramento and San Joaquin Rivers. Several publications of the Department of Fish and Game place great emphasis on the importance of maintenance of proper water quality and temperatures in the North Bay and in the Sacramento San Joaquin Delta in order to protect the striped bass fishery.

While some of the migratory patterns of the striped bass are not clearly understood, it appears that the bass tend to school close to shorelines during their migratory periods, following the rise and fall of the tide. During these periods, the migrating bass are frequently found in the mud flats where temperatures may range from 60-70°F and where their food supply is most plentiful.

The small fish tend to feed upon shrimp and other small crustaceans. The mature fish are voracious eaters, preying on their young and other small fish as well as shrimp, mollusks and sea worms. A stomach analysis of young bass will typically include about 50 percent marine worms, 48 percent crustaceans and 2 percent small fish. For the older fish, crabs, shrimps, small fish and much unidentified organic matter predominate in typical stomach analyses.

The rate of growth of the small fry is rapid. Growth is most rapid beginning in April and extending through September. The bass head for the deeper zones of the channels and sloughs in colder weather where they tend to go through a dormant period of growth, and where their feeding is also at a minimum. One investigator reported that 42 percent of the bass taken for study purposes during one of these periods had empty stomachs.

Table 11 shows the distribution of striped bass angler days during the nine-year period from 1955 to 1964 as reported by the Department of Fish and Game.

Data in Table 11 are supported by catch data available for the years prior to 1935 when commercial stiped bass fishing was permitted, and strongly indicate that the striped bass fishery in the southern end of San Francisco Bay is not nearly as significant as it is elsewhere in the Bay and in the Delta. In its Striped Bass Fishing Map first published in 1967, and

TABLE 11

DISTRIBUTION OF STRIPED BASS ANGLER-DAYS
DURING 1955-1964 IN SAN FRANCISCO BAY AREA

Location	Mean annual angler-days	Percent
Ocean	47,000	3.9
South San Francisco Bay	70,000	5.9
Central San Francisco Bay	136,000	11.4
San Pablo Bay	131,000	10.9
Suisun Bay	59,000	5.0
Delta	640,000	53.8
Other miscellaneous areas	108,000	9.1
	1,191,000	100.0

currently being distributed, the Department of Fish and Game emphasizes only fishing sites and areas in the northern portion of the Bay and in the Delta as being important. The entire south San Francisco Bay area does not appear on the map, indicating its lesser significance as part of the total fishery.

Mention should be made of the problems associated with the striped bass fishery in the California Fish and Wildlife Plan. The plan states that the most damaging wastes discharges include oil, pesticides, heavy metals and other substances that kill fish directly, or make fish unsuitable for human consumption. Heat, turbidity and nutrient loadings are noted as problems that may make the receiving waters unsuitable for fish or fish organisms. Most of the discussion relating to the future prospects for improving the striped bass fishery in the Plan relate to problems associated with the construction of upstream water development projects and to diversions of water from the Delta.

Other Species

A 1966 report by the Marine Resources Operations Laboratory of the Department of Fish and Game provides one of the most complete sources of information on the distribution and relative abundance of fish and shell fish under prevailing environmental conditions in San Francisco Bay. The report also provides significant information on ecological zones within the Bay, including the food of the principal fish and its availability. It is based on the results of 31 sampling cruises conducted at six stations during the period, 1963-65. One of the stations was located immediately south of Dumbarton Bridge.

As many as 30 species of fish were taken at the Dumbarton Bridge station over the three-year period, of which 20 were common to those taken at the other five stations. Anchovies were both more numerous and greater in total weight than all other species combined. Other fish taken included shiner perch, English sole, and Pacific herring. No striped bass or steelhead were taken at the Dumbarton Bridge station during the usual spawning runs at any time during the three-year period.

A comparison of numbers of fish taken near Dumbarton Bridge by months during the three-year study period is presented in Table 12 While by no means conclusive, Table 12 confirms what would be expected, i.e., that the total number fish available in the water column is at a minimum in the winter months when food production is at a minimum.

Another comparison can be made of the numbers of fish species taken at the same station. Table 13 presents such a comparison again by months, and suggests that the diversity of the species is at a minimum during the last half of each year. A comparison of Tables 12 and 13 will reveal that the period of minimum diversity occurs slightly earlier than the period of minimum population.

TABLE 12

NUMBERS OF SPECIES TAKEN NEAR
DUMBARTON BRIDGE BY MONTHS, 1963-65

Month	1963 No.	1963 % of mo. mean	1964 No.	1964 % of mo. mean	1965 No.	1965 % of mo. mean	Mean % of mo. mean
January	-	-	-	-	10	100	100
February	9	100	12	100	-	-	100
March	14	155	17	142	7	70	122
April	16	177	12	100	17	170	149
May	11	122	14	117	16	160	133
June	5	56	13	108	8	80	81
July	-	-	-	-	6	60	60
August	6	67	13	108	11	110	95
September	8	89	6	50	13	130	90
October	3	33	8	67	9	90	63
November	8	89	11	92	9	90	90
December	8	89	10	83	9	90	87
Mo. mean	9		12		10		

TABLE 13

NUMBERS OF FISH TAKEN NEAR
DUMBARTON BRIDGE BY MONTHS, 1963-65

Month	1963 No.	1963 % of mo. mean	1964 No.	1964 % of mo. mean	1965 No.	1965 % of mo. mean	% of mo. mean
January	-	-	-	-	317	12	12
February	702	30	139	11	-	-	21
March	825	36	1,054	86	319	13	45
April	3,668	158	2,360	193	616	24	125
May	914	39	1,272	104	2,559	102	82
June	4,185	180	732	60	467	19	86
July	-	-	-	-	2,003	80	80
August	2,091	90	2,125	174	10,104	404	223
September	2,530	109	3,517	288	10,114	405	267
October	5,004	215	689	56	221	9	93
November	2,025	87	188	15	324	13	38
December	1,291	56	140	11	444	18	28
Mo. mean	2,324		1,222		2,499		

The benthic sampling program reported in the 1966 report was somewhat less conclusive than the fish sampling program. Nevertheless, the results of analysis of bottom samples taken over the period April through December, 1963, revealed a total of seven benthic species taken near Dumbarton Bridge, or less than half the average number of species taken at the other five stations.

The following benthic species were taken at this station from a bottom environment consisting of very sticky mud with no sand or shell:

1. Nereis zonata
2. Neanthes succinea
3. Marphysa sanquinea
4. Mytilus edulis
5. Tapes semidecussata
6. Schizothaerus nuttallii (only species unique to this location)
7. Nassarius obsoletus
8. Urosalpinx cinereus
9. Pachygrapsus oregonensis
10. Pachygrapsis crassipes

The 1966 report also discusses the determination that was made of the relative abundance and seasonal variation of zooplankton from samples collected during the period April, 1963 to February,

1964. At the Dumbarton Bridge, the number of plankton samples collected did not differ much from the average number collected at the other stations. Principal animal forms collected included copepods, calanus, paralabidocera and acartia.

Prospects for Exposure of Biota to Toxicity

From the foregoing discussion, and from the information presented in Chapters II through V and in Appendix A, it is possible to evaluate in general terms the probable impact of the proposed bittern discharge on significant fish and other aquatic organisms in the vicinity of Dumbarton Bridge.

Location of Affected Zone

Results of the theoretical analysis discussed in Chapter V and the hydraulic model tests described in Appendix A, demonstrate that the zone within which the dilution of bittern will be less than 100:1 will extend about two meters horizontally and less than one meter vertically from the discharge ports in the prototype facility. In cross-sectional terms, this zone represents about one percent of the cross-sectional area (pelagic zone) of the channel at MHW when the discharge would occur. Because of the very limited period of the proposed discharge,which would occur only at the peak of the ebb tide flow, none of the waste being discharged would return to the bottom of the Bay at dilution levels of less than 400:1 and, in all probability, will not be discernible from the natural Bay water to benthic organisms.

Feeding and Migratory Habits of Biota

Studies by the Department of Fish and Game and others have shown that the discharge zone is somewhat removed, both vertically and horizontally, from the shallower tidal flats where most of the striped bass and other bay fish seek their food. Furthermore, the zone of such discharge is nearly 30 miles south of the location of principal paths of migration for striped bass and other anadramous fish of San Francisco Bay. The discharge would take place at a time of year other than when striped bass and other anadramous fish would be spawning, and at a time least likely to affect the reproductive processes of such fish. The discharge would take place at a time of year when the total number of fish available in the water column is likely to be at a minimum, and partially during the time of year when the diversity of species is likely to be at a minimum. The discharge would have no known effect on benthic organisms since dilution levels at least twice that required by toxicity tests to assure 100 percent survival will be obtained at all times.

Prospects for Damage to Biota

The length of time of the proposed discharge each day is such that chronic toxicity is not a consideration. Because toxic effects are a function of both time of exposure as well as the concentration of the toxic substance, the prospects for damage to striped bass or other fish of economic significance in the Bay would likely be remote due to the extremely small zone of possible acute toxicity, and the improbability of a fish remaining within such a zone for a sufficient time to receive a lethal or sub-lethal dose of toxicity. The benthic community would not be exposed to bittern at toxic levels under any circumstances. The intermittent nature of the discharge, occurring only during two, two and one-half hour intervals each day, would provide even further protection. The maximum possible time of exposure would therefore represent less than 20 percent of a 24-hour day during the period of discharge, and less than 10 percent of the total time available for the entire year. Such intermittent operation would achieve maximum discharge during short periods of time and high jet velocities that will cause optimum mixing and dilution.

The temperature of the diluted bittern to be discharged to the bay environment would be within 2°-4°C of the ambient water temperature and therefore, well within levels necessary to protect the biota from the adverse effects of heat stimulation.

The pH of the diluted bittern, as discharged to the bay environment, would be about 7.8 as compared with the pH of the ambient water of about 8.1, representing a difference of no biological consequence.

Based on laboratory toxicity tests, the relatively high levels of BOD and COD in the undiluted bittern have no apparent effect or toxic impact on the test fishes, and it must be inferred that toxic effects of the bittern are related primarily to its salinity. If other constituents contribute to the toxic effects of the bittern, their impact appears to be entirely controlled by dilution.

Environmental Impact Statement

The Council on Environmental Quality has published guidelines concerning the preparation of environmental statements as required by the National Environmental Policy Act of 1969. While the policy requires the Corps of Engineers to prepare and submit the statement pursuant to the application for a waste discharge permit, it is hoped that this report will be of material assistance to the Corps of Engineers in that endeavor as well as to State and other Federal agencies which will be requested to comment on the application prior to preparation of the Environmental Impact Statement.

Section 101 (b) of the National Environmental Policy Act itemizes the subject areas to be surveyed in the environmental assessment. Comments on and references to sources of material for each of those subject areas are included in the remainder of this section.

Description of the Proposed Action

A complete description of the proposed action is included in Chapter V, including the plan of the diffuser facilities, the basis for their design, and their estimated capital and annual costs.

Probable Impact on the Environment

A discussion of the impact of the proposed discharge on the fish and other marine organisms of San Francisco Bay is contained in the earlier sections of this chapter. A discussion of the character of the receiving waters in the vicinity of Dumbarton Bridge is contained in Chapter III and a summary of conclusions with respect to the overall environmental impact is set forth in Chapter VII.

While the proposed diffuser will have no adverse effect on navigation during its operation, special care will be required to minimize any interference with navigation by support vessels during the installation period. Special care will be required to provide for the safety of construction personnel and divers during this period as well as during periods when divers would be making their semi-annual inspections and operating the valve.

The diffuser will be secured to the existing pipeline owned by Leslie Salt Company in such a manner that it will not become a navigational hazard resulting from its displacement during storms and heavy current movement. It is anticipated that much of the diffuser will be fabricated on shore and that the period of time required for underwater construction activities will be rather limited. Existing Federal and State navigation laws and regulations, together with standard terms and conditions attached to all construction and waste discharge permits issued by the Corps of Engineers , will govern the conduct of support vessels and divers during all phases of the underwater operations. State safety laws and regulations administered by the California Department of Industrial Relations will also have application. All such operations will be conducted during daylight hours or under such other restrictions as may be deemed appropriate by the Corps of Engineers and hence, no particular navigational hazards are anticipated.

Probable Adverse Environmental Effects Which Cannot be Avoided

As noted in an earlier section of this chapter, and in Chapter VII, it is highly improbable that the proposed waste discharge will impose any significant, long-range effect on the marine environment. Two possible changes or damage to existing life systems in the Bay have been noted, which bear some discussion, but which cannot necessarily be construed as a "probable adverse environmental effect" as used in the National Environmental Quality Act of 1969.

It has been shown there will be no adverse environmental impact on benthic organisms as a result of the proposed discharge. That portion of the food chain for the striped bass and higher forms of aquatic life will therefore be unaffected. However, it is conceded that some plankton and other microscopic animal life will from time to time be exposed to the discharge of dilute bittern in the immediate vicinity of the discharge ports. The effect of the level of toxicity at that location on these forms is not known, nor is the effect of their possible diminution on the remaining portions of the food chain known. For example, it is known from stomach analyses that a significant portion of the diet of fish does not necessarily consist of living organisms of a lower order. Even if plankton or other microscopic portions of the food chain were damaged, it cannot be inferred, therefore, that the resulting impact will be adverse.

It is also recognized that both small and larger fish may occasionally swim through the zone of one of the discharge plumes wherein the dilution level may be less than 100:1. However, the impact of any residual toxicity which may remain in that portion of the plume cannot be considered great because of the extremely small zone of exposure and because the toxic impact will be a function of both concentration and time of exposure. The probable time of exposure, and hence, the long-range impact, cannot be significant. The location of the diffuser and the time of discharge each year have been specifically chosen so that the discharge will not affect anadromous fish during their spawning runs, i.e., the most critical period of the reproductive cycle.

Alternatives to the Proposed Action

As indicated in Chapter I, two alternatives to the proposed form of discharge no longer exist. For the foreseeable future, the bittern has no great economic value and its use as a source of certain salts other than sodium chloride is no longer of commercial significance to the Leslie Salt Company. Also, it was the practice in earlier years prior to the adoption of present water quality standards by the Federal and State governments to discharge the bittern directly to adjacent sloughs or shallower portions of San Francisco Bay near the bittern ponds. This practice is no longer acceptable because of the probable adverse environmental impact. Further, the cost to correct the probable damage to the marine environment from the former practice would be substantially greater than any other alternative, including that recommended herein.

The only remaining alternative disposal method would be to store the bittern as is being done at present. The long-range utility of this method is questionable owing to the ever-increasing amount of land area that must be devoted to this purpose. Because the rate of bittern evaporation would not keep up with bittern production, increasingly greater acreages of land would be devoted to bittern storage and decreasing acreages of land would be available for salt production. The reduced production of salt would eventually combine to result in an uneconomical and probable unprofitable salt producing enterprise.

Relationship Between Local Short-Term Uses and Long-Range Productivity

The proposed discharge would return to the Bay a material originally derived from the Bay, except for the removal of sodium chloride. The method of discharge can be accomplished with no significant adverse environmental impact, and would constitute a total recycling of a natural resource.

The south end of San Francisco Bay has been found to have a number of problems resulting from poor circulation of the bay water and from the present discharge of sewage and other wastes in partially treated form. The proposed waste discharge of Leslie Salt Company would have no effect on the existing quality of the receiving waters, and, upon discharge, could not be discerned from natural bay water.

Irreversible and Irretrievable Commitments of Resources

There would be no known irreversible or irretrievable commitment of the valuable resources of San Francisco Bay as a receiving water for the proposed discharge except for the removal of the sodium chloride, and no other irreversible or irretrievable commitment would be made other than the resources and manpower expended. The monitoring program which would be established by the California Regional Water Quality Control Board as part of any approval it may give to the proposed discharge would be adequate to detect any such problems. Such information, if discovered, would be the basis for future possible revisions in the waste discharge standards. The California Regional Water Quality Control Board would retain continuing jurisdiction over the discharge under provisions of the California Porter-Cologne Act, and rules and regulations adopted pursuant thereto. If the decision were made to abandon the project after a period of years of operation, the permanent loss of fish, wildlife and their habitats would be insignificant.

Problems and/or Objections Raised by Federal, State and Local Agencies

No concerns or questions, other than those noted in this report by the California Department of Fish and Game, are known to exist. It is believed that all such concerns have been adequately investigated and reported upon herein, to the extent that all provisions of applicable Federal and State water quality standards will have been satisfied. Formal comments from all appropriate Federal, State and local agencies will be requested by the Corps of Engineers prior to finalization of the formal environmental impact statement and issuance of a construction and waste discharge permit.

VII. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

As a result of this investigation and report, the following conclusions have been drawn:

1. The proposed discharge of bittern to San Francisco Bay, as described herein, has engineering feasibility and economic justification, subject only to the establishment of waste discharge standards by the California Regional Water Quality Control Board and the issuance of a construction and waste discharge permit by the United States Army Corps of Engineers.

2. The proposed waste discharge would have no certain significant adverse impact on the marine environment.

3. The only available alternative methods of disposal of bittern, i.e., by storage and evaporation, or by direct discharge to the intertidal zone, are either more costly and economically unjustified, or environmentally unacceptable.

4. The proposed discharge would occur at a time, at a location, and in such a manner that the impact on the striped bass fishery would be insignificant.

5. A substantial factor of safety would be provided, both in the timing of the discharge and the resulting small size of the zone of possible toxicity, so as to provide reasonable protection to the benthic and pelagic life of San Francisco Bay, and the discharge would conform in all other respects with existing Federal and State laws and regulations.

6. The proposed discharge does not sacrifice the maintenance and enhancement of the long-term productivity of the valuable natural resources of San Francisco Bay for any short-term expedient use.

7. The proposed waste discharge would not make any irreversible or irretrievable commitment of the resources of San Francisco Bay, except for the removal of sodium chloride crystals and the direct manpower and resources expended.

Recommendations

Based on the foregoing conclusions, it is recommended that:

1. The Leslie Salt Company make application to the California Regional Water Quality Control Board, San Francisco Bay Region, for the establishment of waste discharge

standards for the waste discharge project contemplated herein, pursuant to the Porter-Cologne Act.

2. The Leslie Salt Company make application to the District Engineer, United States Army Engineer District, San Francisco District, for a combined construction and waste discharge permit for the contemplated waste discharge project, pursuant to the Rivers and Harbors Act of 1899.

3. The California Regional Water Quality Control Board and the District Engineer give favorable consideration to said applications of the Leslie Salt Company on the basis of the conclusions set forth in this report.

4. Upon receipt of approval by the California Regional Water Quality Control Board and the District Engineer, the Leslie Salt Company proceed with the design and construction of the recommended waste discharge facilities.

APPENDIX A

REPORT ON MODELING OF JET DILUTION FOR THE PROPOSED LESLIE SALT BITTERN OUTFALL DIFFUSER, SAN FRANCISCO BAY

By

E. J. LIST, Ph.D.

January, 1972

MODELING OF JET DILUTION
FOR THE PROPOSED LESLIE SALT
BITTERN OUTFALL DIFFUSER,
SAN FRANCISCO BAY

by

E. J. List Ph.D.

Prepared for

CDM Environmental Engineers

Pasadena, California

January, 1972

Report to CDM Environmental Engineers

on

Modeling of Jet Dilution for the Proposed Leslie Salt

Bittern Outfall Diffuser, San Francisco Bay

by

E. J. List Ph.D.

1. Introduction

CDM Environmental Engineers have proposed an outfall and diffuser as the solution to the bittern disposal problem facing Leslie Salt Co. at their South San Francisco Bay production facility. This report describes the results of a model study of a section of the proposed diffuser. Jet dilution contours and downstream concentration profiles as given by conductivity measurements at various simulated tidal velocities are presented. Photographs of the flow configurations are also given.

2. The Proposed Diffuser

The proposed diffuser is to lie in 40 feet of water approximately 100 yards south of the Dumbarton Bridge across South San Francisco Bay, (Reference 1). It is anticipated that it will be 24 inches in diameter, 625 feet long, with 1 inch diameter ports spaced at 6 feet centers, angled at 60^{o} to the horizontal, and discharging bittern diluted with an equal volume of sea water at 30 feet per second.

The temperature and salinity of the bittern before dilution is described in the pond readings (Reference 2) and from a study of these records and the recorded Bay water salinity and temperature as a function of depth (Reference 3) we have accordingly selected the following possible range of bittern and Bay water properties (the Bay is well mixed with depth at this location (Reference 3)):

Specific gravity of bittern ρ_b : 1.29

Specific gravity of Bay water ρ_a : 1.015 - 1.026

Thus, the dilution of bittern by an equal volume of Bay water gives a discharge specific gravity of 1.152 - 1.158.

The diffuser jet parameters are therefore:

Jet velocity U_o = 30 feet/sec.

Discharge density ρ_d = 1.152 - 1.158

Bay water density ρ_a = 1.015 - 1.026

Port diameter d = 1 inch

Gravitational constant g = 32.2 feet/sec/sec.

The jet Froude number is therefore

$$F = \frac{U_o}{\sqrt{\frac{\rho_d - \rho_a}{\rho_a} \cdot gd}} = 50.0 - 51.5$$

The tidal velocities at the proposed discharge location were recorded by U.S.G.S. at Dumbarton Bridge during the period May 11-15, 1953, (Reference 4). The range of velocity at the 35 feet deep level at maximum ebb tide was found to be between 1.4 and 1.8 knots, equivalent to 2.3 - 3.0 feet per second. Thus, the minimum ratio of jet to current velocity is approximately 10:1. The minimum velocity at 1 1/2 hours before or after maximum ebb tide is 0.7 knots or approximately 1.2 feet per second, corresponding to a jet to current ratio of 25:1.

The minimum velocity at 2 hours before or after maximum ebb tide is 0.8 feet per second; this corresponds to a jet velocity to ambient velocity ratio of 37:1.

3. The Model

The entire diffuser was not modeled, just one six foot section containing a single exit port. The intention was to obtain the jet dilution contours and concentration profiles downstream of a single jet in order to determine the mixing efficiency of each exit port. The distance downstream at which adjacent jets coalesced was also to be determined.

A successful jet model must have the following features:

(i) The Froude numbers of model and prototype must be equal. Since the Froude number measures the ratio of the jet momentum flux to jet buoyancy flux, equality of Froude numbers means that the ratio of these two quantities will be correct.

(ii) The ratio of the jet velocity to current velocity must be equal in model and prototype.

(iii) The jet discharge angle must be identical in model and prototype.

(iv) The model jet Reynolds number must be sufficiently large that the model jet is fully turbulent in order that the jet mixing is similar. ($U_o d/\nu$ must be at least 2000.)

(Strictly speaking the Reynolds number in the model ambient flow should be at least the same order of magnitude as the prototype ambient flow but this is obviously impossible to accomplish. However, this is not too serious a problem since most of the initial mixing is independent of the turbulence scale in the ambient flow. In any case, the model flow turbulence scale is much smaller and should give conservative dilution results even when the ambient turbulence does become important.)

In view of the prototype data given above we must have the model jet Froude number approximately 50 and the flow velocity ratios in the range 10:1 to 37:1. In view of the size of the test facility available (a maximum of 2 feet deep) we chose a 1/8th scale model. The port then becomes 1/8-inch diameter in the model. Since a concentration of 1 gram/liter is a very convenient level to measure in the laboratory we chose the jet concentration to be 100 grams/liter. This corresponds to a jet specific gravity of 1.066 and since the laboratory water supply has a specific gravity of essentially 1.000 at ambient temperature, the corresponding model jet velocity will be that which gives the model jet Froude number 50. Thus,

$$U_o \text{ model} = 7.4 \text{ ft/sec}$$

and the corresponding volume flux for the 1/8-inch diameter port was 17.9 milliliters/second. The jet Reynolds number was 7200.

A velocity ratio of jet to ambient flow of 10:1 then corresponds to an model ambient current of 0.75 ft/sec., the 25:1 ratio corresponds to a model ambient current of 0.30 ft/sec. and the 37:1 ratio to 0.2 ft/sec. model current.

The prototype and model data are summarized in the following table.

Variable	Prototype	Model
Jet velocity	30 ft/sec	7.4 ft/sec
Jet diameter	1 inch	1/8 inch
Discharge specific gravity	1.152 - 1.158	1.066
Ambient specific gravity	1.015 - 1.026	1.000
Jet Froude number	50.0 - 51.5	50
Ambient velocity	0.8 - 1.2 - 3.0 ft/sec	0.2 - 0.3 - 0.75 ft/sec
Velocity ratio (jet to ambient)	37:1 - 25:1 - 10:1	37:1 - 25:1 - 10:1
Length scale	8	1
Velocity scale	4	1

5. The Experiments

Six experiments were carried out* corresponding to the data given in the table.

* For details of experimental setup and method see Appendix.

Experiment	Froude No.	Jet Angle	Prototype Tidal Velocity	Tide
1	50	60°	3.0 ft/sec	Max ebb
2	50	60°	1.2 "	Max ebb $\pm$ 90 min
3	50	60°	0.8 "	Max ebb $\pm$ 120 min
4	50	60°	0 "	Slack water
5	40	90°	1.2 "	Max ebb $\pm$ 90 min
6	50	90°	1.2 "	Max ebb $\pm$ 90 min

Jet dilution contours and the jet plan form were measured for experiments 1 through 4. Experiments 5 and 6 were photographed only.

Experiment 1 is shown in the photographs of Figures 1 and 2; the corresponding dilution contours and concentration profiles are shown in Figures 3 and 4. From Figure 1 it appears that the jet never touches the bottom of the channel and this is essentially confirmed in the jet dilution contours shown in Figure 3. We note that the jet mean centerline appears to remain more than 1 meter (3 feet) above the bottom. However, in Figure 4 we see that at 180 centimeters downstream from the jet in the model, corresponding to approximately 14.5 meters in the prototype, the concentration on the bottom is 0.25 gms/liter equivalent to a dilution of 400:1 (800:1 bittern dilution because of the predischarge dilution of the bittern with an equal volume of seawater). The 200:1 dilution contour was approximately 40 feet long, 24 inches deep and not more than 6 feet wide (prototype dimensions). The 100:1 dilution was less than 16 feet long, less than 15 inches deep and no wider than 4 feet. The 50:1 dilution contour was no longer than 7 feet, about 6 inches deep and no wider than 2 1/2 feet. Thus, jets from adjacent ports will intersect almost at the limit of the 200:1 dilution region so that the minimum dilution in the region where all jets coalesce will be at least 200:1 (400:1 bittern dilution). The bottom dilution will be at least 400:1 as stated above.

In experiment 2, shown in Figures 5,6,7, and 8, the jet centerline did not rise higher than 6 feet from the bottom (prototype dimensions) and when the jet returned to the bottom the dilution was 400:1 at the 10 meter mark and was approximately 250:1 at the 13 meter mark (Figure 8). Furthermore, since the maximum average concentration on the jet centerline had become equivalent to a dilution of approximately 240:1 the concentration on the bottom will never exceed that equivalent to a dilution of 240:1 (480:1 bittern dilution). In the photograph, Figure 5, the jet can be seen to be touching the bottom, as the concentration measurements shown in Figure 8 predict. The 200:1 dilution contour was approximately 36 feet long, 30 inches deep and no wider than 6 feet. It did not come closer than 30 inches to the bottom.

The 100:1 dilution contour was at most 18 feet long, 29 inches deep and 4 feet wide. The 50:1 contour was no longer than 8 feet, no more than 12 inches deep and no wider than 3 feet, (Figure 7). From the upper figure in Figure 7 it is clear that jets from adjacent ports will again intersect at about the limit of the 200:1 dilution contour and that the minimum dilution in the region downstream of the coalescence will be 200:1. The minimum bottom dilution in this region will be at least 240:1 as shown in Figure 8, (this corresponds to a bittern dilution of 480:1). These concentrations would occur at approximately 1 1/2 hours before and after maximum ebb tide and correspond to a mean tidal velocity of 0.8 knots or 1.2 feet per second at the 35 feet deep mark.

Experiment 3, corresponding to a tidal velocity of approximately 0.5 knots or 0.8 feet per second, shows that at this velocity the jet centerline returned to the bottom; which is shown quite explicitly in Figure 9. The corresponding jet dilution contours, Figure 11, and concentration profiles, Figure 12, confirm this. In Figure 10, a plan view of the jet, it can be seen that the jet has spread quickly over the bottom directly after impact. The maximum average bottom concentration appears to be equivalent to a dilution of about 110:1, Figure 12, and occurs in the model at 100 cm.

downstream of the exit port, or 8 meters (26 feet) in the prototype. It appears that a region on the bottom of at least 130 square feet would be exposed to a dilution of between 100:1 and 200:1 for each exit port. The 50:1 dilution contour was approximately 10 feet long, as much as 20 inches deep and no wider than 6 feet. However, this dilution is exceeded at all points past the maximum elevation of the jet trajectory. All the diffuser jets would coalesce at approximately 25 feet downstream of the diffuser.

No concentration experiments were taken in experiment 4, since it was readily apparent that discharge at slack water would lead to a large area of the bottom covered with a dilution in excess of 50:1. This can easily be seen in the two photographs of the jet shown in Figures 13 and 14. Since the time scale in the model is half that for the prototype, the photographs shown correspond to about 1 minute and 5 minutes after the jet was started in the model. As shown in the photographs the heavy material moved in both directions from the exit port.

Two qualitative experiments were done at a 90° jet angle and these are shown in Figures 15, 16, and 17. Figure 15 is for a jet Froude number of 40, corresponding to a model discharge velocity of 5.9 feet per second, or a prototype discharge velocity of 24 feet per second. The cross stream velocity in the prototype is 1.2 feet per second. The plume can be seen to be impacting the bottom at about the same point that a 60° jet does with a Froude number of 50 and a cross velocity of 0.8 feet per second. This is confirmed by the rapid spread shown downstream in the plan view of Figure 16. For a jet Froude number of 50, Figure 17, the behavior of the 90° jet appears to be almost identical with that for a 60° jet, c.f. Figure 5.

It should be noted that the dilution contours drawn in all the figures are mean dilutions corresponding to mean concentrations. The peak concentrations at any point were measured to be as high as twice the mean. But, it must be remembered that the peaks only occur for a relatively short time, maybe less than a second or so as a high concentration eddy moves by. The mean concentrations as portrayed in the figures given are those concentrations that would be experienced by an organism remaining almost continuously at that point for at least 10-15 seconds.

6. Conclusions

The conclusions to be drawn from the experiment depend to a large degree on the maximum mean concentration that is desired at the bottom of the channel. If the maximum mean concentration at the bottom is to be that equivalent to a minimum dilution of 100:1 (200:1 bittern dilution) then there appears to be no problem whatsoever associated with operating the diffuser for ± 2 hours of maximum ebb tide. If the maximum bottom concentration is to be less than that equivalent to a 200:1 dilution (400:1 bittern dilution) then the diffuser must only be operated ± 1 1/2 hours of maximum ebb tide. Should the minimum bottom dilution to be permitted be 50:1 (100:1 bittern dilution) then it would appear that the diffuser could well be operated almost from slack water to slack water. Figures 3, 7 and 11 show that the 50:1 dilution contour does not extend far beyond point of maximum altitude of the jet and since the mixing in this region of the jet is almost all by jet turbulence the speed of the crossflow will not influence this to such a degree that material of a dilution less than 50:1 would fall to the bottom.

From all of the experiments it is apparent that there is a large amount of undisturbed water over the diffuser. The jets, or rather the influence of them, does not appear to extend much higher than 2 meters from the bottom except at slack water where the jet is estimated to rise to a height of approximately 3 meters or 10 feet from the bottom. Since the Bay is about 13 meters or 40 feet deep at the diffuser site this allows at least 30 feet of undisturbed water above the diffuser.

Experiments with a 90° jet showed no distinct advantage over a 60° jet at the Froude number of 50 and in equal cross flows. In point of fact there may well be an advantage at very slow cross flows for a 60° jet since it does add horizontal momentum to the discharge and clears it away from the diffuser site more quickly.

The results obtained from the experiments described herein may be used for any 60° jet with a Froude number of 50 provided the ratio of jet to crossflow velocity is maintained and the lengths are scaled accordingly.

References

1. Letter to Willard Greenwald, Dept. of Fish and Game. CDM, December 3, 1971.

2. Leslie Salt Co. Pond readings December 18, 1970 - December 10, 1971.

3. U.S.G.S. Personal communication to CDM December 16, 1971.

4. U.S.G.S. Personal communication to CDM December 16, 1971.

Appendix

The Experimental Setup and Method

A 1/8-inch diameter jet was located in the center of a two foot wide flume and initially angled at 60° to horizontal. The jet was connected to a constant head supply via a glass Fisher-Porter flowrater and control valve. The experimental setup is shown diagrammatically in Figure A. The flume is provided with precision rails upon which is mounted a carriage with a Vernier depth and width traversing mechanism. A conductivity probe comprising two platinum black coated 0.010 inch diameter platinum wires 1/16 inch long mounted on a long insulated shaft, (visible in Figure 1), is attached to the traversing mechanism and connected electrically to a solid state Sanborn AC-DC Carrier preamplifier and recorder via a Wheatstone bridge circuit. The conductivity probe, bridge amplifier and recorder form a conductivity measuring instrument which was calibrated with sodium chloride solutions of known concentration in order to determine the concentration profiles downstream of the jet and hence the dilution contours.

An experiment proceeded as follows:

(i) Calibrate the flowrater.

(ii) Adjust the channel flow for the desired ambient velocity.

(iii) Calibrate the conductivity measuring apparatus.

(iv) Adjust the jet flow rate for the desired jet velocity.

(v) Traverse the conductivity probe down through the jet and across the jet at the level of maximum concentration. Repeat for the number of desired locations.

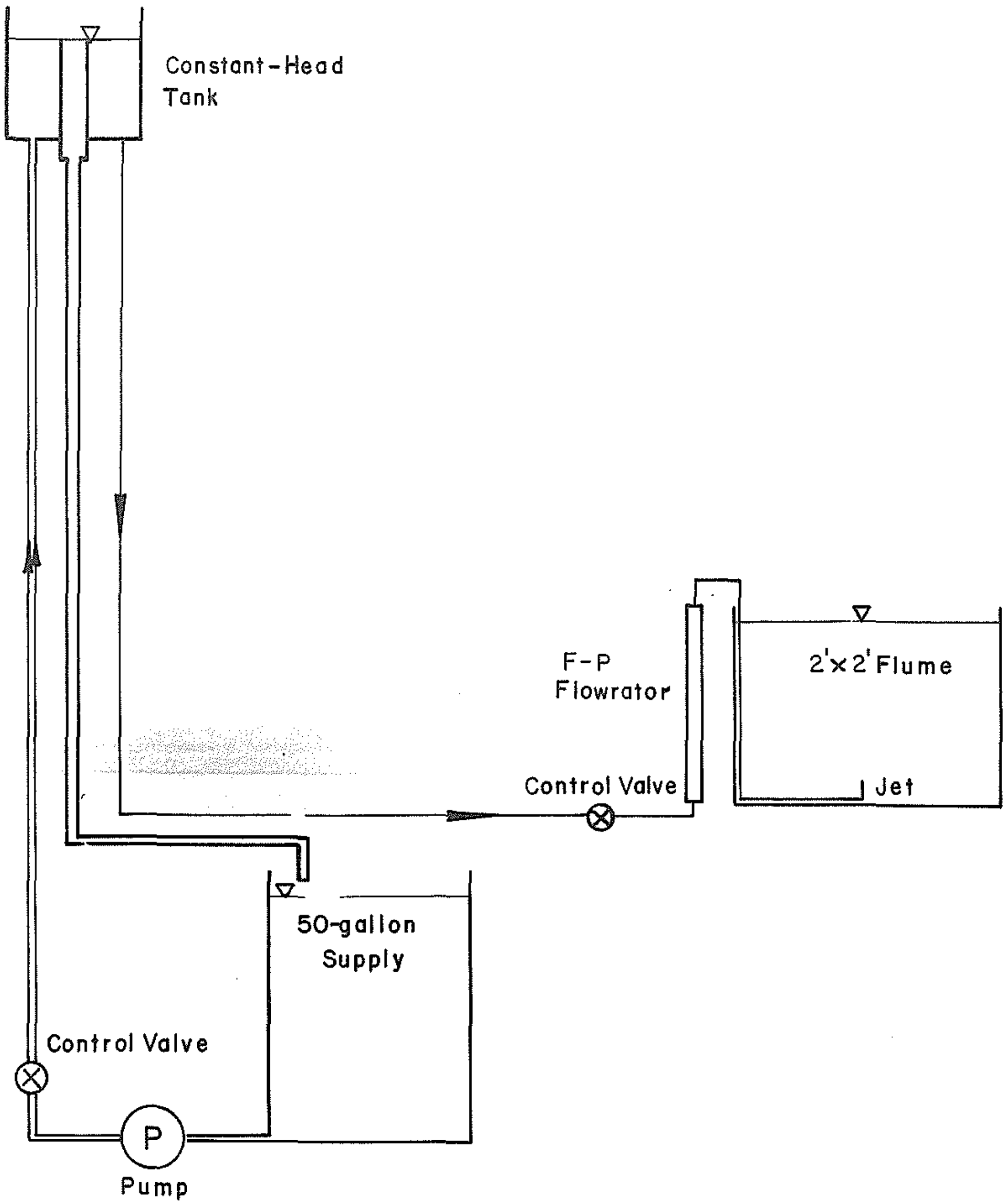

FIGURE A: EXPERIMENTAL SET-UP

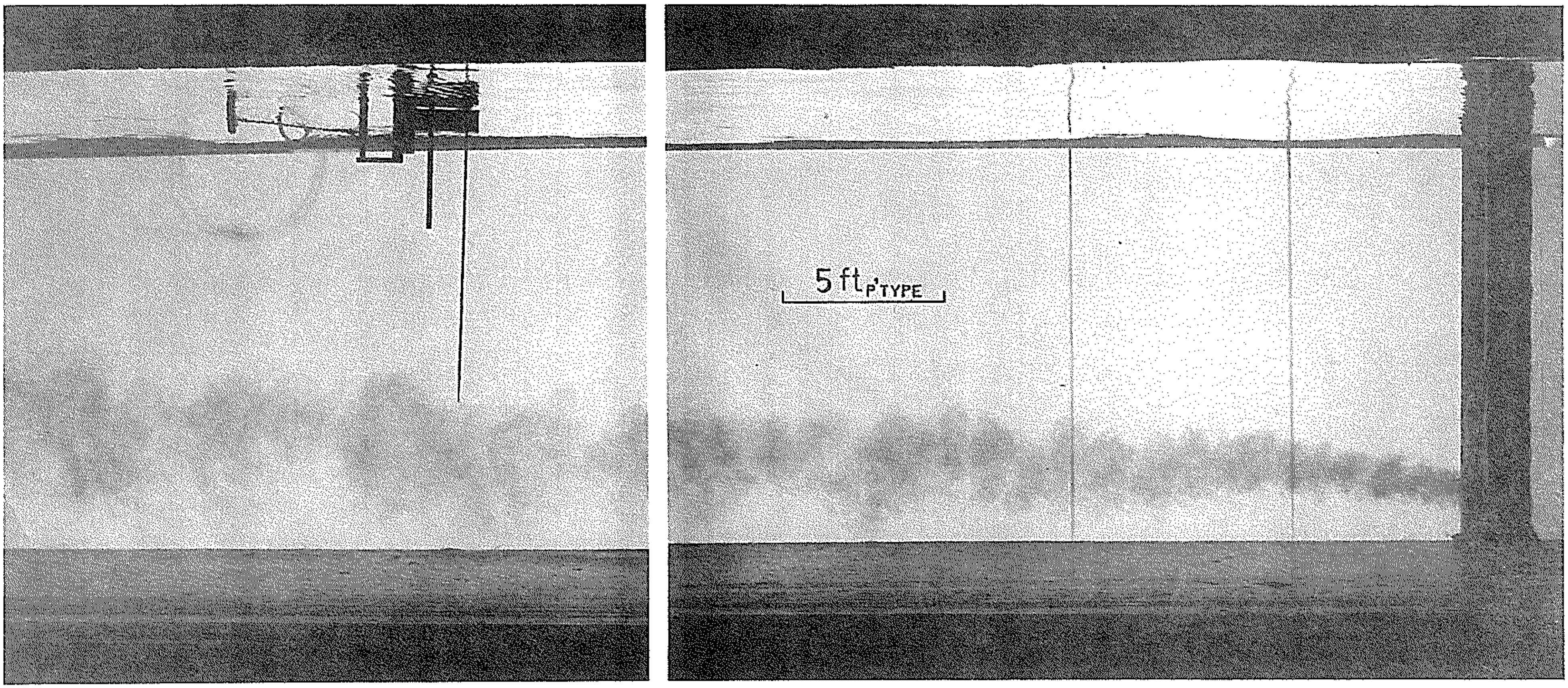

Figure 1: Experiment 1 - Jet Froude number 50, mean tidal velocity 3.0 feet per second at 35 feet deep (Elevation view).

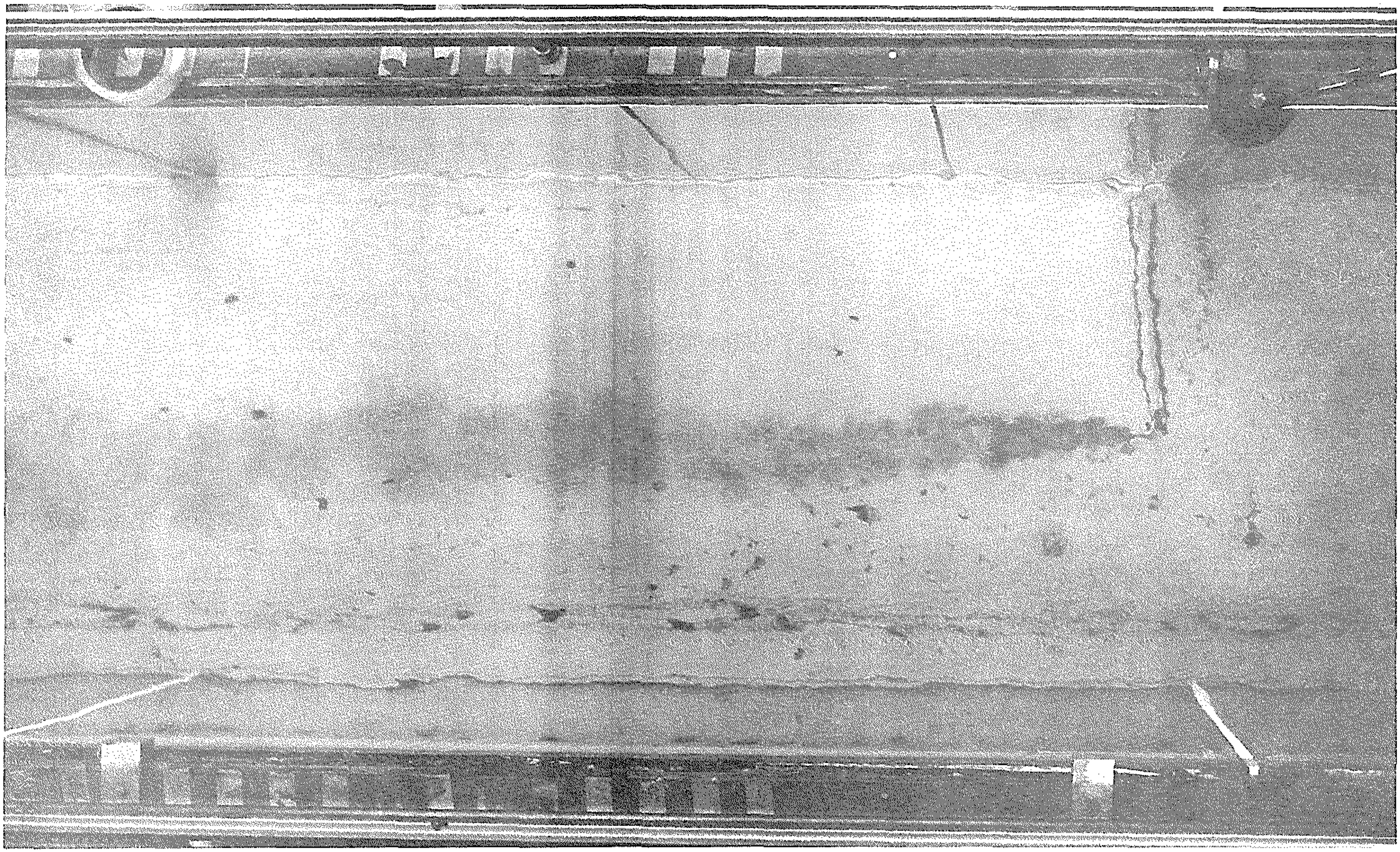

Figure 2: Experiment 1 - Jet Froude number 50, mean tidal velocity 3.0 feet per second at 35 feet deep (Plan view).